

MULTIMEDIA



UNIVERSITY

STUDENT ID NO

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MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2015/2016

ENT4086 – DIAGNOSTIC TECHNOLOGY (NE)

3 MARCH 2016
09:00 a.m. - 11:00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 7 pages with 4 Questions only.
2. Attempt **ALL FOUR** questions. The distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.
4. Please refer to APPENDIX at page 7 for the table of binding energies.

QUESTION 1

- (a) With the aid of a suitable diagram, explain the operating principles of magnetic force microscopy (MFM). [4+4 marks]
- (b) (i) Given an atom with one electron in its inner orbital being ejected. With the aid of energy level diagrams, describe the **TWO** possible electronic transitions that will bring the atom from excited state to ground state. [4+4 marks]
- (ii) Name the **TWO** elemental detection techniques used for the electronic transitions mentioned in (b)(i) above. [2 marks]
- (c) (i) Explain how Fourier transform infrared spectroscopy (FTIR) works. [4 marks]
- (ii) State the selection rules for *IR (infrared) active* and *Raman active* molecular vibrations, respectively. [2 marks]
- (iii) Give **ONE** application of FTIR spectroscopy. [1 mark]

QUESTION 2

- (a) (i) Discuss the surface charging effect that will be encountered during the measurement of a non-conductive sample using scanning electron microscopy (SEM). Suggest **TWO** possible approaches that can be adopted to eliminate the charging effect. [4+2 marks]
- (ii) How can the contrast of an SEM image of a specimen with limited contrast be increased? Justify your answers. [2+4 marks]
- (b) Depth resolution in a depth profile is a measure of the broadening of an abrupt interface brought about by the effects of instrumental and physical process of sputtering. Briefly discuss the **TWO** following factors that limit depth resolution. Suggest methods that can be used to improve the resolution in each of the cases:
- Ion mixing
 - Crater edge effect
- [6+3 marks]

Continued...

- (c) Suggest which mode of secondary ion mass spectroscopy (SIMS), *static* or *dynamic*, is suitable to be used to examine the surface chemical information of a sample. Briefly justify your suggestion.

[1+3 marks]

QUESTION 3

- (a) **Figure Q3(a)** shows the X-ray photoelectron spectroscopy (XPS) spectrum of a palladium (Pd) sample obtained using magnesium (Mg) K_{α} X-ray. It can be seen that five main peaks occur at kinetic energies of 330, 690, 720, 910 and 920 eV. Assume that the spectrometer work function is negligible. Using the table of binding energies as shown in the Appendix, answer the following:

- (i) Calculate the respective binding energy of the photoelectrons based on the main peaks shown.

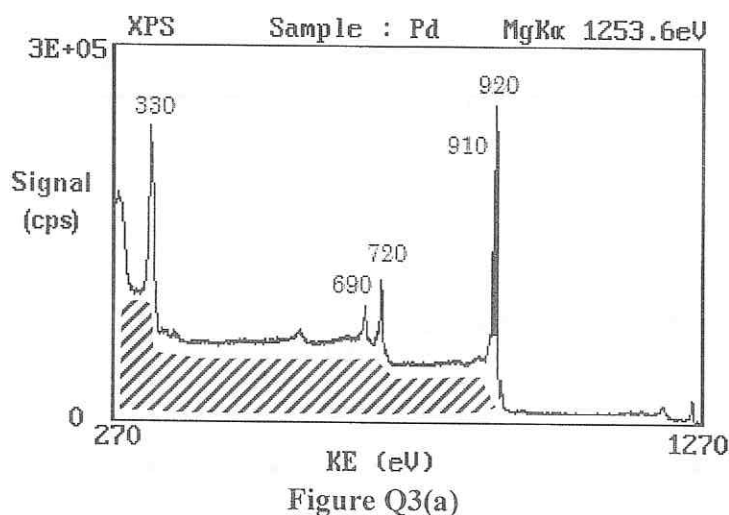
[5 marks]

- (ii) Identify the respective energy levels from which the photoelectrons are emitted.

[5 marks]

- (iii) Briefly discuss the factor that contributes to the highlighted region in the spectrum.

[2 marks]



Continued...

- (b) **Figure Q3(b)** shows the ion scattering spectroscopy (ISS) spectrum of a 2 keV helium (He^+) ion scattered from a polyvinyl chloride (PVC) surface that comprises of carbon (C), oxygen (O), sodium (Na), chlorine (Cl) and tin (Sn). Given the atomic number, Z , of the surface elements: $Z=6$ (C), $Z=8$ (O), $Z=11$ (Na), $Z=17$ (Cl) and $Z=50$ (Sn), map each peak (a to e) to the respective element. Briefly justify your answer.

[5+2 marks]

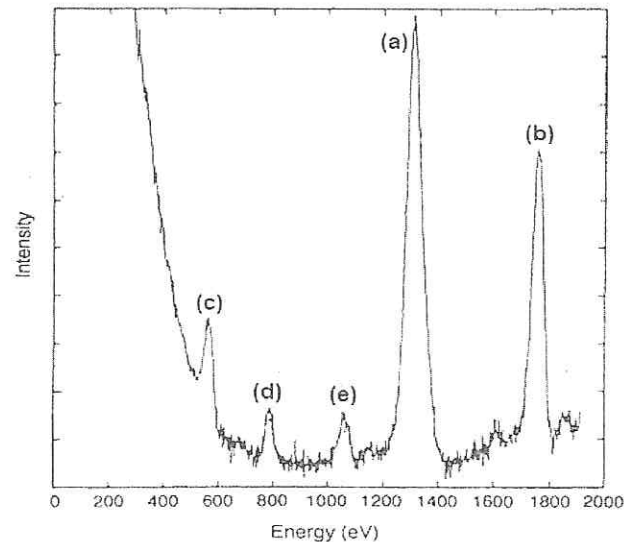


Figure Q3(b)

- (c) **Figure Q3(c)** shows the secondary ion mass spectroscopy (SIMS) depth profile of a trilayer structure deposited on steel (iron-carbon alloy) substrate. Analyze the spectra in terms of the constituent materials and the thickness of each layer.

(Note: O and Ar are impurities)

[6 marks]

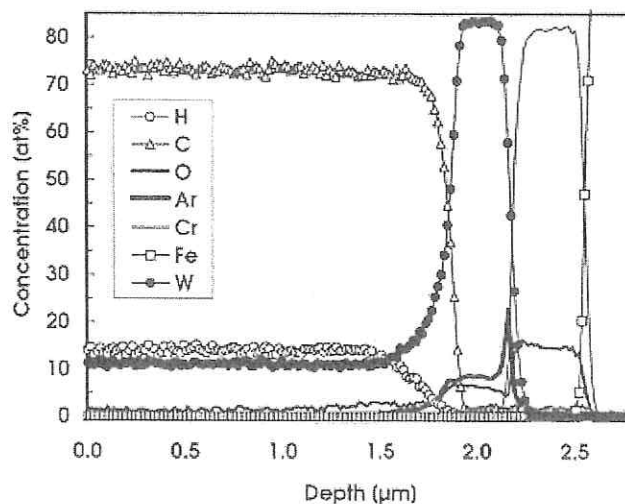


Figure Q3(c)

Continued...

QUESTION 4

(a) The bright-field (BF) and dark-field (DF) transmission electron microscopy (TEM) images of nanosized ceria (CeO_2) powders are as shown in **Figures Q4(a)(i)** and **Q4(a)(ii)**, respectively. Answer the following:

- (i) Differentiate the BF and DF image formation mechanisms in TEM. [2 marks]
- (ii) Under what conditions will the electron beam be absorbed or diffracted, without being transmitted through the sample? [3 marks]
- (iii) Estimate the average crystallite sizes based on the observation from the TEM images in **Figures Q4(a)(i)** and **Q4(a)(ii)**. [1 mark]
- (iv) Briefly give an analysis on the uniformity of the *size* and *shape* of the measured nanopowders. [3 marks]

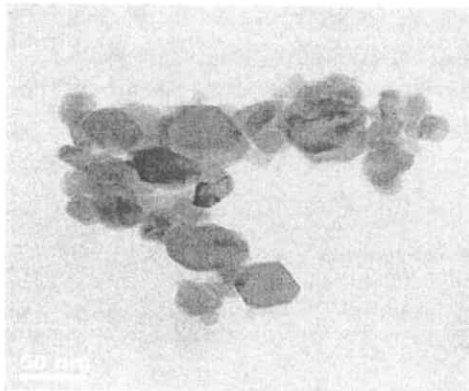


Figure Q4(a)(i)

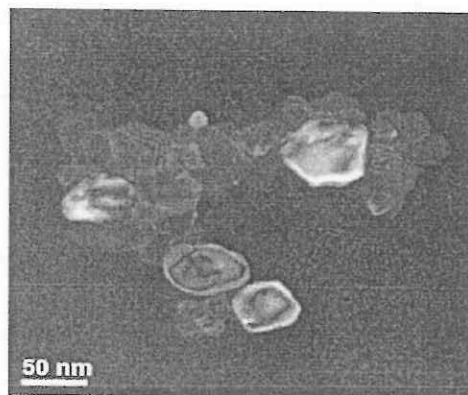


Figure Q4(a)(ii)

(b) **Figure Q4(b)** shows the X-ray diffraction (XRD) pattern of the nanosized CeO_2 powders characterized in **Question 4(a)**. Answer the following:

- (i) Analyze the XRD pattern as shown in **Figure Q4(b)**. [4 marks]
- (ii) Estimate the average crystallite size of the CeO_2 powders using Scherrer's formula. Given that the X-ray wavelength of Cu-K_α is 0.15405 nm and full width at half maximum (FWHM) of the (111) peak is 0.1206° . [3 marks]
- (iii) Comment on the consistency of the crystallite sizes obtained from both the XRD pattern and TEM image (in **Question 4(a)(iii)**). [2 marks]

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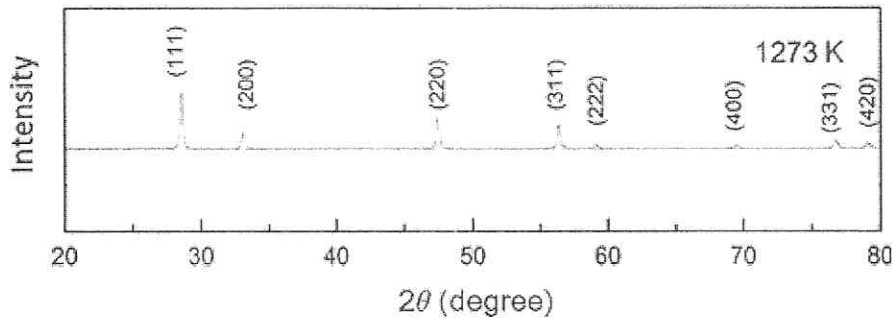


Figure Q4(b)

- (c) (i) A Raman spectroscopy system with an argon-ion excitation source operating at 514.5 nm is used to detect a sample that contains nitrogen (N_2). Given that the N_2 Stokes line appears at 584.6 nm, calculate the Raman frequency-shift that will be observed in the resulting spectrum.

[3 marks]

- (ii) Figure Q4(c) shows the Raman spectra for boron-doped diamond films with different doping concentrations, whereby spectrum A to F are corresponding to the films with increasing doping concentrations. The peak that can be seen at 1332 cm^{-1} is the characteristic diamond line. Based on the observation from the spectra, evaluate the films (A to F) in the context of *crystallinity* and *strain*, respectively.

[2+2 marks]

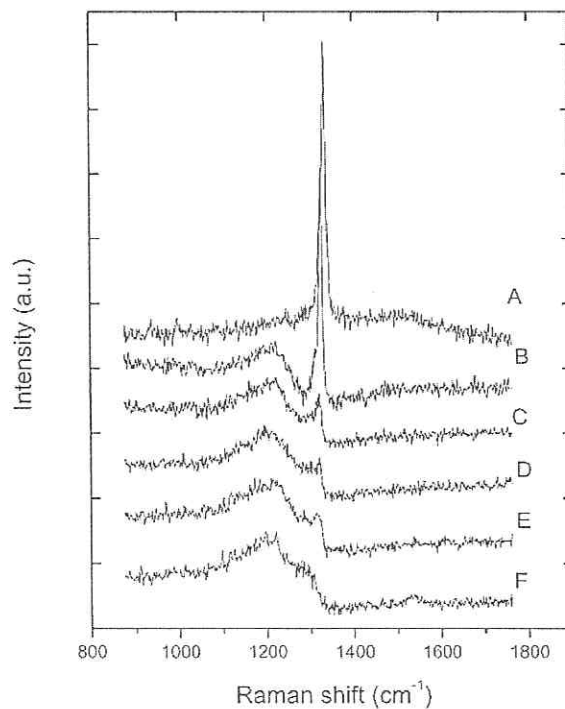


Figure Q4(c)

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APPENDIX

Binding energies of some elements

Z	El	1s _{1/2} K	2s _{1/2} L ₁	2p _{1/2} L ₂	2p _{3/2} L ₃	3s _{1/2} M ₁	3p _{1/2} M ₂	3p _{3/2} M ₃	3d _{3/2} M ₄	3d _{5/2} M ₅
1	H	14								
2	He	25								
3	Li	55								
4	Be	111								
5	B	188			5					
6	C	284			6					
7	N	399			9					
8	O	532	24		7					
9	F	686	31		9					
10	Ne	867	45		18					
11	Na	1072	63		31	1				
12	Mg	1305	89		52	2				
13	Al	1560	118	74	73	1				
14	Si	1839	149	100	99	8				
15	P	2149	189	136	135	16		10		
16	S	2472	229	165	164	16		8		
17	Cl	2823	270	202	200	18		7		
18	Ar	3202	320	247	245	25		12		
19	K	3608	377	297	294	34		18		
20	Ca	4038	438	350	347	44		26		5
21	Sc	4493	500	407	402	54		32		7
22	Ti	4965	564	461	455	59		34		3
23	V	5465	628	520	513	66		38		2
24	Cr	5989	695	584	577	74		43		2
25	Mn	6539	769	652	641	84		49		4
26	Fe	7114	846	723	710	95		56		6
27	Co	7709	926	794	779	101		60		3
28	Ni	8333	1008	872	855	112		68		4
29	Cu	8979	1096	951	932	120		74		2
30	Zn	9659	1194	1044	1021	137		90		9
31	Ga	10367	1299	1144	1117	160		106		20
42	Mo	20000	2866	2625	2520	505	410	393	208	205
46	Pd	24350	36304	3330	3173	670	559	531	340	335
48	Ag	25514	3806	3523	3351	718	602	571	373	367
73	Ta*	67416	11681	11136	11544	*566	*464	*403	*24	*22
79	Au*	80724	14352	13733	14208	*763	*643	*547	*88	*84

* 4s, 4p ci 4f levels indicated, respectively

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